Before the
Federal Communications Commission

Washington, DC 20054

In the Matter of	|	
Request for Waiver of Measurement	|	ET Docket No. 04-352
Procedures for OFDM Ultra-Wideband Devices	|	

Reply to comments of: decaWave

decaWave is a semiconductor company designing ultra wideband communications devices and a member of the UWB forum which promotes a direct sequence spread spectrum pulse based approach for ultra wideband communications (DS-UWB).

1. Introduction

In their Request for a waiver of certain measurement procedures, the MBOA-SIG claim that:

"III. Test Data Confirms that MB-OFDM Systems Pose No Greater Threat Of Harmful Interference Than Pulsed UWB Systems Already Permitted By The Rules."

In the subsequent paragraph it is claimed that amplitude probability distribution plots (APDs) support this view. This reply presents simulation data which shows that this is not true and that MB-OFDM poses a greater threat of harmful interference.

In comments which apparently support this view "COMMENTS OF PHILIPS ELECTRONICS NORTH AMERICA CORPORATION" APDs are given which suggest that an Pulse based UWB systems working at 1MHz produces more harmful interference that MB-OFDM. This reply presents simulation results which show that MB-OFDM is more harmful than a 1MHz Impulse based UWB modulation scheme.

Comments have already been presented by decaWave which show analytically that DS-UWB, a very high pulse rate UWB system, is less interfering to an uncoded BPSK victim receiver. This reply goes further by presenting simulation results of interference from 3 types of UWB systems transmitting at the same average power spectral density.

2. Simulation Particulars

2.1. Victim Receivers

Two types of victim receiver were simulated. The first type of victim receiver simulated uses binary PSK (BPSK) modulation protected by a convolutional code. The second type uses quaternary PSK (QPSK), protected by the same convolutional code. The convolutional code chosen was a rate ½ code with constraint length K=6 and polynomial [53, 75]. The receivers use uncoded bit rates of 10.25 Mbps and 20.5Mbps respectively at a symbol rate of 20.5MHz and a receiver 3dB bandwidth of 20.5MHz. The corresponding transmitter uses a root raised cosine transmit pulse shape with 75% excess bandwidth and a receive band limiting filter has the same characteristics.

These particular receiver modulation schemes were chosen for these simulations because they are typical of those currently used in digital radio communications. Many variations are possible, e.g. a different FEC scheme, a different bit rate, QAM modulation. We would expect similar results with these variations.

2.2. Interfering Transmitters

The three interfering UWB transmitters were simulated. A DS-UWB transmitter, an MB-OFDM transmitter and a 1MHz Pulse based impulse UWB transmitter. The DS-UWB transmitter was simulated by transmitting 1GHz pulses with random polarity. (Note tests with 100MHz and 200MHz pulses showed almost identical performance, as did tests with white gaussian signals)

The MB-OFDM signal was simulated by transmitting a 1GHz gaussian signal for 242ns followed by a pause for 677ns. This corresponds to the parameters specified in the waiver request document. The signal transmitted in the other two bands of the 3 hop system was not transmitted since this would be filtered out by the victim receiver's front end filters.

The 1MHz e UWB transmitter was simulated by transmitting a very wideband pulse with random polarity at 1MHz.

All three interferers were normalised to the same spectral power density.

Monte Carlo simulations were run for both types of victim receiver, the error rates were measured under 4 situations.

1) AWGN interference.
2) DS-UWB + AWGN interference.
3) MB-OFDM + AWGN interference.
4) 1 MHz Impulse + AWGN interference.

In order to to allow inspection and to ensure that these results are reproducible by the FCC, Decawave is willing to supply the Matlab code which simulated this to the FCC upon request.

The tests were run for 2×10^6 bits for each data point in the simulation.

3. BPSK Results

The BPSK simulations were run for a range of AWGN signal to noise ratios (SNR) and each AWGN level was run at a range of signal to interference ratios (SIR)

Firstly, the simulation was run with just AWGN, i.e. with no UWB interferers with the following results:

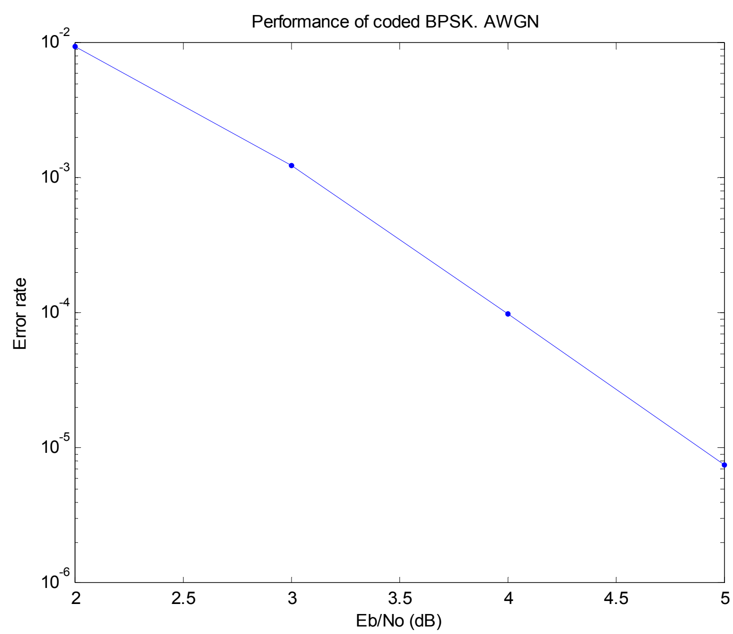

Figure 1. AWGN performance

This agrees very well with the predicted performance of the combination of BPSK and this particular convolutional code.

3.1. BPSK interference at AWGN of 6dB

The BPSK simulation was run with interference from the three UWB systems at a fixed SNR of 6dB i.e. an EbNo of 6dB. (EbNo = SNR for rate ½ coded BPSK)

This is an extreme case which will be rarely encountered in the real world because it only allows 1dB of margin for a bit error rate of 10^{-5}.

Figure 2 is a plot of the error rate vs SIR for this case for the 3 UWB systems.

It can be clearly seen that both the 1MHz impulse rate pulsed UWB (light blue) and the DS-UWB systems cause less errors than the MB-OFDM system. At any given error rate, the MB-OFDM interference is approximately 1dB worse than either of the other two UWB systems.

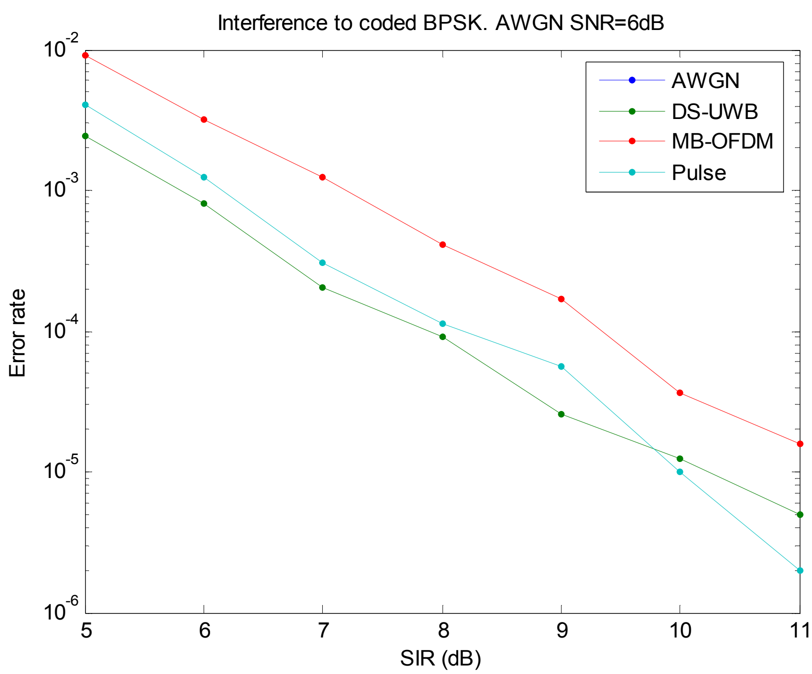

Figure 2. BPSK interference comparison at AWGN = 6dB SNR.

3.2. BPSK with AWGN at 9dB SNR

This was repeated at a fixed AWGN SNR of 9dB (EbNo of 9dB)

This allows 4dB of margin for a bit error rate of 10^{-5}.

Figure 3 is a plot of the error rate vs SIR for this case for the 3 UWB systems.

Again, both the 1MHz impulse and the DS-UWB systems cause fewer errors than the MB-OFDM system. At 10^{-5} error rate, the MB-OFDM interference is approximately 2dB worse than either of the other two UWB systems.

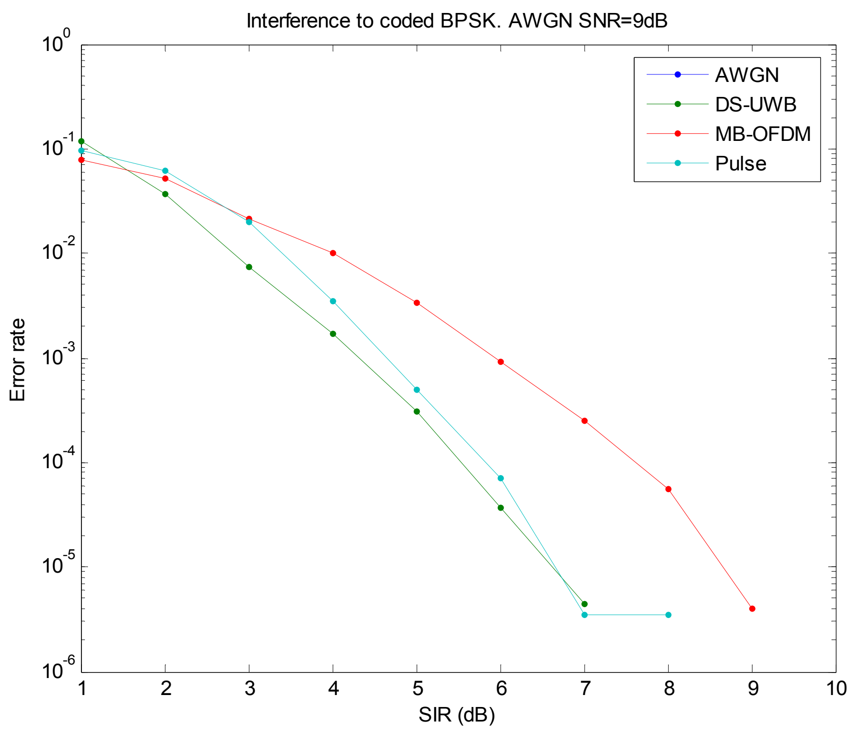

Figure 3. BPSK interference comparison at AWGN = 9dB SNR.

3.3. BPSK with AWGN at 12dB SNR

This was repeated at a fixed AWGN SNR of 9dB (EbNo of 9dB)

This allows 4dB of margin for a bit error rate of 10^{-5}.

Figure 3 is a plot of the error rate vs SIR for this case for the 3 UWB systems.

Again, both the 1MHz impulse and the DS-UWB systems cause fewer errors than the MB-OFDM system. At 10^{-5} error rate, the MB-OFDM interference is more than 2dB worse than DS-UWB and more than 3dB worse than the 1MHz impulse based system.

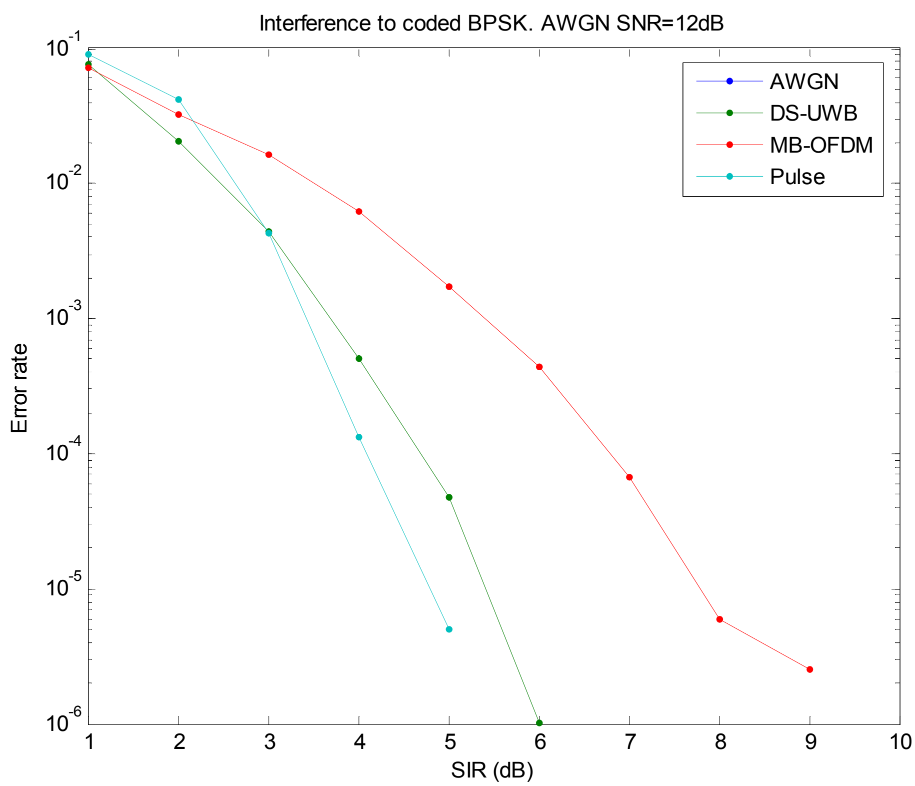

Figure 3. BPSK interference comparison at AWGN = 12dB SNR.

4. QPSK Results

The same interference simulations were run for QPSK also for a range of AWGN signal to noise ratios (SNR) and each AWGN level was also run at a range of signal to interference ratios (SIR)

The performance graphs for these test are shown below in figures 4, 5 and 6. Again the MB-OFDM systems interferes considerable more than either the 1MHz impulse based system or the DS-UWB system. How much worse the interference is rises as the error margin of the victim receiver rises. We would expect that AWGN levels which were lower again would show an even bigger gap.

QPSK at the same symbol rate as BPSK requires 3dB more Eb/No for the same error rate performance: This means that the 1dB margin occurs at 9dB SNR. For this reason the tests were run with 9dB, 12dB and 15dB SNR.

Table 1. below summarizes the QPSK results along with the previous BPSK results.

		SIR required for BER of 10^{-5}				
Modulation	AWGN SNR	MB-OFDM SIR	1 MHz Pulse SIR	DS-UWB SIR	1MHz Pulse advantage	DS-UWB advantage
BPSK	6dB	~11.5dB	10.2dB	10.2dB	~+1.3dB	~+1.3dB
BPSK	9dB	8.5dB	6.5dB	6.5dB	+2.0dB	+2.0dB
BPSK	12dB	7.8dB	4.7dB	5.3dB	+3.1dB	+2.5dB
QPSK	9dB	13.8dB	13.3dB	12.5dB	+0.5dB	+1.3dB
QPSK	12dB	11.7dB	10.3dB	9.3dB	+1.4dB	+2.4dB
QPSK	15dB	10.8dB	8.8dB	8.4dB	+2.0dB	+2.4dB

Table 1. Interference results summary

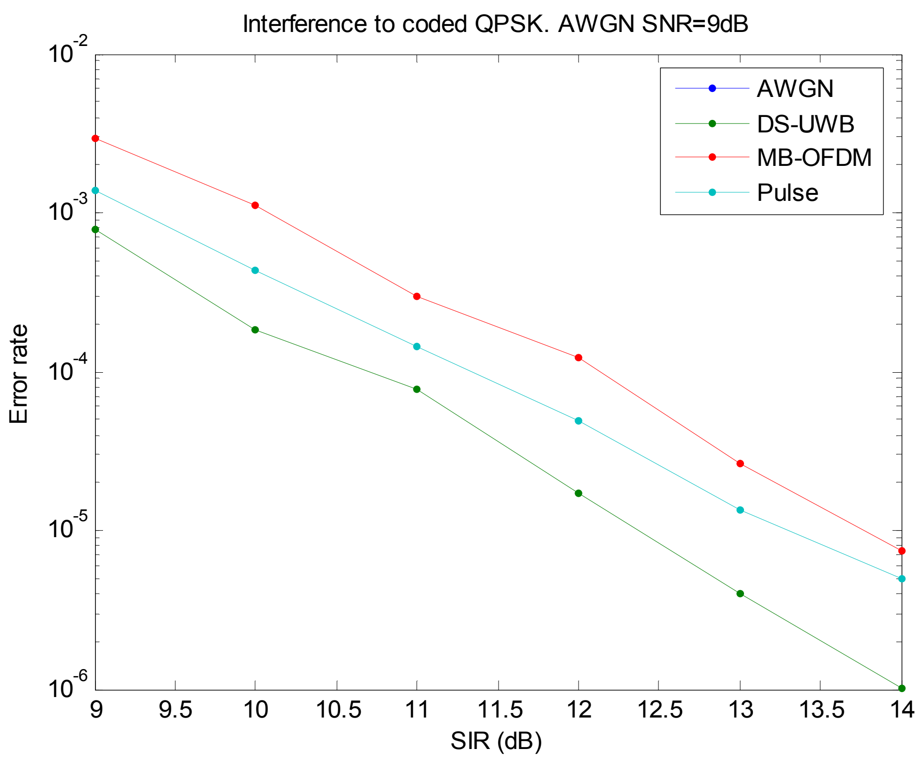

Figure 4. QPSK interference comparison at AWGN = 9dB SNR.

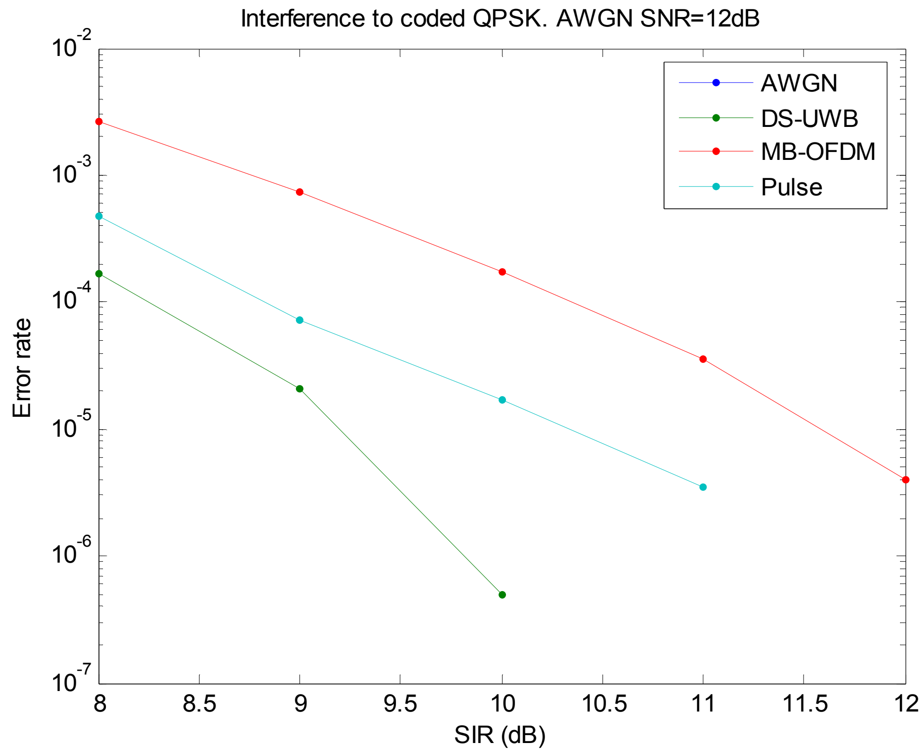

Figure 5. QPSK interference comparison at AWGN = 9dB SNR.

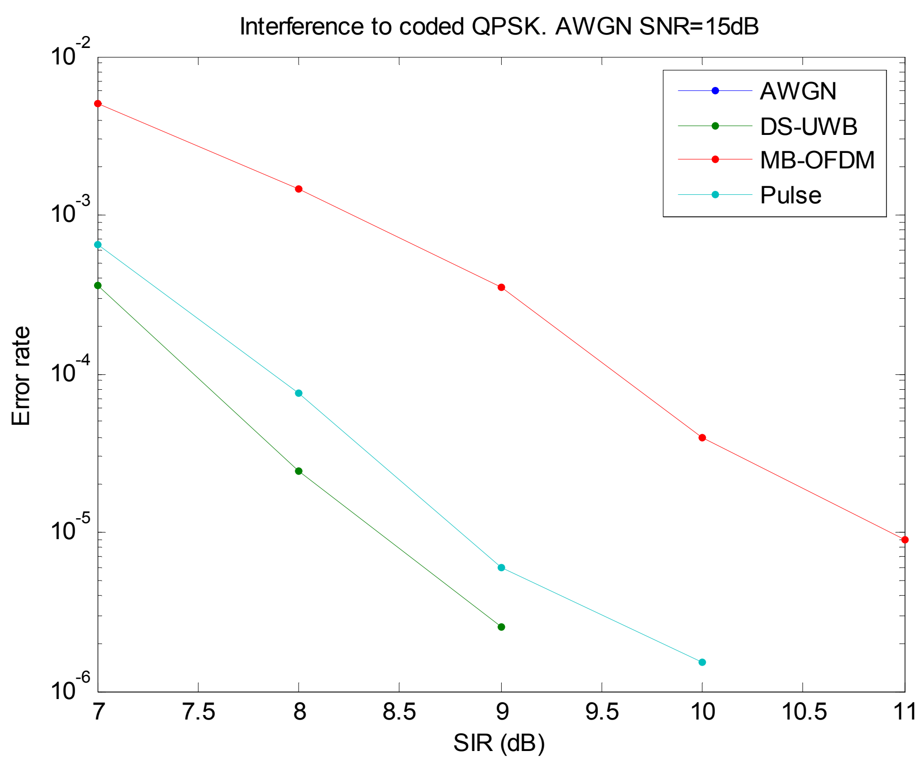

Figure 6. QPSK interference comparison at AWGN = 9dB SNR.

5. Summary

Simulations have been run for two typical victim receivers. These simulations have tested the error rates introduced by three types of ultra wideband interferers. MB-OFDM, DS-UWB and a 1MHZ Impulse based UWB. These tests have shown that, for these victim receivers, the MB-OFDM interference is always worse than the two pulse based interferers, sometimes more than 3dBs worse. For a summary of results see the last two columns of Table 1.

For this reason, and the reasons outlined in its earlier comments, Decawave asks the Federal Communications Commission not to grant the MBOA the waiver they have requested.

References

[1] J. G. Proakis, *"Digital Communications,"* McGraw Hill, Second Edition, 1989. **Table 5.3.13**